PILOT OPERATING HANDBOOK

DJI S-1000/Zenmuse

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This book is offered in a format so that pilots can customize the checklists to their exact needs. Please print out this handbook, make notes while watching the video regarding the checklist, then change the wording and order to suit your needs. Then print out the revised form and laminate it in plastic. Carry it you're your aircraft. Then use it every time you operate your aircraft. Keep the log books regarding the following:

1) Pilot flight time
2) Aircraft flight time
3) Aircraft maintenance and updates
4) Battery usage, date put into service, voltage, mah vs time

Print out and make readily available the error message legend of various flashing lights. Know what to do without hesitation should you observe warnings.

Insurance is a must! Not only will it be expensive to repair your aircraft in the event of an incident, if you injure bystanders or damage other people's property you are liable for damages which could run into the millions of dollars. One insurance company which currently writes policies on sUAS is www.Transportrisk.com

Errors & Omissions should be sent to customerservice@troybuiltmodels.com. We will promptly update the POH for everyone to have the latest updates available.

KEY PARAMETERS

Max Takeoff Weight: 24 lbs
Weight with Zenmuse and all other equipment – no camera, no battery: 13.4 lbs
Weight of Nex5/6/7 camera: 1 lb
Weight of Canon 5D camera: 1.75 lbs
Max Battery Weight with Zenmuse/Nex Camera: 9.5 lbs
Max Battery Weight with Zenmuse/Canon 5D: 9 lbs
Flight Times using 90% of battery:

16,000 mah battery Nex 7: 17 min
20,000 mah battery Nex 7: 20 min
32,000 mah battery Nex 7: 22 min

Flight times using the Canon 5D or other cameras similar in weight will reduce the flight times by about 1 minute. These times are averages in our tests. You may get longer or shorter flight times based on weight and flying style, though these numbers should be fairly accurate.

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DJI S-1000/Zenmuse

CHECKLISTS

- **DJI S-1000 BENCH SET UP & TESTS**
  - All screws/bolts are tight
  - Timer alarm for flight time to not exceed 80% battery capacity set properly
  - Batteries are secure
  - Antennas are secure
  - Props balanced
  - Props aligned
  - Props not chipped
  - Check blades, arms, etc. for cracks/damage
  - Wiring Tight
  - No excessive flexing of motors or booms
  - Booms/motors will not twist
  - Center of gravity is correct
  - Warning lights set for low battery if used
  - Batteries charged. Replace any battery which cycles below 80% of rated capacity
    - Laptop Battery
    - Flight Battery
    - Handheld Rx Battery
    - RC Tx Battery
    - Video Rx Battery
    - Spare Laptop Battery

- **DJI S-1000 INVENTORY CHECKLIST**
  - Load Flight plan
  - Aircraft
  - Camera with SD card
  - Spare parts/tools
  - Spare batteries
  - Two RC transmitters
  - Laptop
  - Battery Charger
  - Flight Controller Cable
  - Video monitor, stand, battery, antennas
  - Goggles
  - Datalink & cable
  - Battery Y-harness

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- **DJI S-1000 PREFLIGHT CHECKLIST**
  - Check area to fly on Google maps
  - Confirm walkie talkie and ATC coms operation
  - Inform ATC of your flight plan if required
  - Determine emergency flight plan and alternate landing zones avoiding power lines and obstacles
  - Check wind direction
  - Set a perimeter of 50-100 meters – area must be clear of people
  - All antennas (9?) installed and all pointing in correct directions
  - Engage GCS, monitor, laptop, goggles, etc. (bring up flight plan)
  - Remove lens cap / Clean lens
  - Camera On
  - Ensure camera has SD card installed.
  - Check battery voltage
  - Install battery on copter.
  - Check CG
  - Level copter with front pointing in correct direction for course lock – do not turn on
  - On Copter TX - Set switches - Throttle Down, Return to Home switch Off, Manual Flight Mode Switch On, Flight Path Switch Off – Not Course or Home Lock
  - Copter Transmitter On
  - Check Model Selection on Tx
  - Check Tx battery voltage (above 7.4v)
  - On Photo Tx – set switches - HDMI switch Off, Freestyle switch On
  - Photography Transmitter On
  - Check Model Selection on Tx
  - Check Tx battery voltage (above 7.4v)
  - Plug in battery black lead first.
  - Calibrate GPS/Compass if necessary
  - If calibrated, cycle battery with correct heading for course lock.
  - Do not touch the Copter until 30 seconds after full GPS Lock. Initial 3 red blinks is normal meaning no GPS lock. Wait until no flashes. Continue with checklist.
  - Check Copter Voltage from GCS
  - Engage Attitude Mode – Must Achieve Double Amber Flash
  - Engage GPS Mode – Must Achieve Double Purple Flash
  - While in GPS mode engage “Course Lock” mode. Must achieve green Flash
  - Do not engage motors. Set throttle to center position. Must achieve single amber flash in Attitude Mode and single purple flash in GPS mode
  - HDMI switch On (video on camera itself should go off)
  - Freestyle switch On (FPV Off)
  - Verify camera operation (If problems, check Drive Mode – Remote Cmdr must be “on”, manual focus, intelligent auto)
  - Verify data link if installed – rolling copter manually should change gauges
  - Upload flight plan
  - Verify altitude is about 0 via gauge on computer/GCS/video monitor/goggles
  - Timers set properly

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- **TAKEOFF CHECKLIST**
  - Declare intentions for takeoff with ATC
  - Engage GPS mode – Double purple flash
  - Engage Course Lock mode (double green flash)
  - Announce loudly: "CLEAR PROP"
  - Position the sticks in the lower left hand corners, then immediately raise the throttle 2 clicks, and center the right stick.
  - Advance throttle to ¼ power for 5 seconds. Assure all motors are operating.
  - Verify that left/right and forward/back stick movement engages the proper motors
  - Verify data and video links are still operational
  - Announce loudly: "TAKING OFF"
  - Advance throttle to full. Copter must jump off of the ground.
  - Ascend to 3 meters. Center throttle stick. Should be single green flash. Verify wireless link, GPS hold, camera operation, gauges, etc. are working properly.
  - Verify course lock is operational by rotating 90 degrees and pushing forward on stick.
  - Verify copter stability. If unstable, land and reset gains, recalibrate, or retest as necessary.
  - Raise landing gear
  - Proceed with manual mission
  - For autopilot operation
    - Ascend to 10 meters manually
    - Engage autopilot
  - Manual pilot/observer must monitor the informational LED and be ready to take over in manual mode when necessary.
  - Manual pilot to request copter flight battery voltage readout from camera operator periodically.

- **QUICK PREFLIGHT CHECKLIST**
  - Landing zone clear
  - Level copter with correct heading
  - Battery 4.1+ full, 3.8 depleted
  - Camera on. SD card in.
  - Both TX – all switches down
  - Both TX on
  - Copter on
  - Check GPS and Course lock checks
  - Video check
  - Photo check
  - Timers ready
  - Takeoff
  - Raise Landing Gear
  - Unplug 6 batteries upon landing

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- **ERROR MESSAGES**
  - White flashes
    - IMU malfunction. Land and determine cause. Possibilities:
      - GPS/Compass not pointing forward
      - IMU not pointing forward
      - Set up of X, Y, Z for location of IMU and Compass is incorrect
  - Excessive rocking/instability possible causes:
    - Weak motor
    - Structure flexing from fatigue or cracks
      - Motor mount
      - Main frame
      - Booms
    - Loose Bolts causing flexing or misalignment
      - Props
      - Mounts
    - Props out of balance
    - Props misaligned
    - Excessive wind speeds or gusts
    - Excessive Gains
    - Excessive motor power. Max motor power must a little more than typical ascent power.
  - Red Flashes (1, 2 or 3 flashes with pauses) – GPS loss (3 is more serious). Land if loss lasts for more than 30 seconds. Possible causes:
    - Clouds
    - Structures
    - GPS mal-function
    - GPS too close to electrical components
    - GPS vibration
- **LANDING CHECKLIST**
  - Landing area clear
  - Lower landing gear
  - Note obstacles in flightpath
  - Announce loudly: “LANDING”
  - First cut power to the aircraft
  - Note elapsed time of flight
  - Adjust any parameters (camera servo speed, exponential, etc)
  - Turn power off to transmitters, camera, goggles, monitors, Rxs, etc.
  - Touch motors to verify temperatures are similar
  - Complete flight log
    - Date and time of flight
    - Batteries used
    - Time of Flight
  - Contact ATC

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SECTION 1
GENERAL

NOTE: In an effort to minimize costs and maximize spare parts availability, many COTS (commercial off the shelf) components have been utilized. Some may have slight modifications to better suit this application. Most COTS products have separate data sheets, assembly manuals and instruction manuals. They are reference in this document, with key factors being emphasized.

As with all high technology products utilizing constantly evolving software, it is important to periodically check for online upgrades to the COTS components, including hardware, firmware and software.

WARNING: Great care must be taken with the batteries. Much of this manual and supplemental information is devoted to the use and care of the batteries, especially the flight batteries. They are less volatile than gasoline, though they should be treated with the same respect. Become very familiar with proper techniques of their use.

- GENERAL CHARACTERISTICS
  - Primarily for ISR (Intelligence, Surveillance, and Reconnaissance)
  - Economical due to extensive use of COTS products
  - Low Visual Signature
  - Low Aural Signature
  - Quick Launch and Recovery
  - Short Training Period
  - Simple Operation
  - Waypoint Navigation
  - Backpackable
  - VTOL
  - Quick Repairs
  - Redundant Flight Systems
  - Safety Return to Home during lost link or low battery
  - High Degree of Mission Success
  - GPS navigation aid
  - Various sensors
  - 24 lb max takeoff weight
  - Operating Temp Range: -5°C to +60°C
  - Flight Modes: Manual and GPS aided waypoint navigation
  - Maximum Operating Altitude: 1000 meters
  - Maximum Operation Wind Conditions: 10 m/s
  - Propulsion System: LiPoly batteries
  - Takeoff: Manual or Automatic
  - Landing: Manual or Automatic
  - Takeoff/Recovery Area: 5m square

- IMPORTANT DIMENSIONS
  - Distance rotor to rotor across the center: 41”
  - Height with GPS/Compass folded down: 21”
  - Height with GPS/Compass up: 25”
  - Length of landing gear skids: 18”
  - Distance between landing gear skids: 21”

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- IMPORTANT WEIGHTS
  - Weight including Nex 7 camera, Zenmuse gimbal, A2 autopilot system, landing gear, data transceiver, RC transceiver, video transmitter, regulators and all wiring – everything except battery: 13.4 lbs
  - Maximum Takeoff Weight: 24 lbs
  - Battery Weight: up to 9.5 lbs with Nex camera and Zenmuse Gimbal

- MOTORS
  - Manufacturer: DJI-Innovations
  - Number of motors: 8
  - Motor type: 41mm x 14mm
  - Motor Model Number: 4114-11
  - Motor KV/RPM: 400
  - Motor max @ 25.2V: 10,000 rpm
  - Motor Max Power: 500 Watts
  - Power rating: 4000 Watts maximum power consumption for all 8 motors
  - Current Max: 100 amps
  - Amp Draw Typical Average: 65 amps

- PROPELLERS
  - Manufacturer: DJI-Innovations
  - Material: Composite
  - Number of propellers: 8
  - Propeller model number: DJI 15 x 5.2
  - Number of blades: 2 - folding
  - Propeller Diameter: 15”
  - Propeller Pitch (fixed): 5.2”
  - Max rpm: 10,000 rpm

- ELECTRONIC SPEED CONTROLS
  - Manufacturer: DJI-Innovations
  - Number of speed controls: 8
  - Speed control model number: DJI 40A Opto
  - Rating in amps: 40 Amps continuous
  - Signal Frequency: 30 - 450 Hz
  - Drive PWM Frequency: 8 KHz

- AUTOPILOT
  - Manufacturer: DJI-Innovations
  - Autopilot Model Number: DJI A2
  - Components: GPS/Compass, IMU, Master Controller, Power Distribution System, LED Indicator Lighting System, Data Transceiver, GCS Software
  - Power Consumption: 5W
  - Operating Temp Range: -5°C to +60°C
  - Software Compatible: Windows XP sp3 / Windows 7
  - Hovering Accuracy: Vertical : ± 0.5m; Horizontal: ± 2m

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- WIRELESS LINKS
  - Distributor: DJI-Innovations
  - Frequencies:
    - 2.4 Ghz datalink with WiFi
    - 2.4 Ghz Command & Control
    - 5.8 Ghz Video
  - Power Consumption: 1 watt
  - Usable Range: Less than 2 km.

- FUEL/FLIGHT BATTERY
  - Manufacturers: Various COTS suppliers
  - Battery chemistry recommended: Lithium Polymer
  - Battery Capacity: 16,000 - 42,000 mah
  - Battery cell count required: 6S (6 cells in series)
  - Battery Voltage: 21V minimum during hover, 22.2V nominal, 25.2V maximum
  - Battery Minimum Rated Discharge Rate: 20C minimum
  - Battery Minimum Charge Rate: 1C (3C preferable)
  - Battery Rest Time between discharging and charging: 0-30 minutes
  - Batteries used simultaneously: 1-4
  - Recommended Battery Discharge Amount: 80-90%

- FLIGHT PARAMETERS
  - Flight Time: up to 30 minutes
  - Payload Max: 11 lbs
  - Power Consumption in a Hover at 21 lb takeoff weight: 1500 Watts, 65 amps

- ***WARNINGS***
  - Never power a video transmitter or receiver without an antenna connected or overload failure will occur.
  - Read all information regarding batteries contained in this manual and supplements.
  - Batteries are highly flammable and can explode, especially when fully charged. Improper charging, vibration, impact, high discharge, etc. can lead to explosion and fire. Batteries must be charged under constant supervision and using proper precautions.
  - Batteries fully charged must be handled with extreme care.
  - Batteries must not be stored above 50% charged state.
  - Store batteries between 20% - 50% charged state. Fully charge just before use.
  - Fully charged batteries which are not to be used within 24 hours should be discharged to 20% - 50% charged state.
  - Discharging LiPoly batteries in excess of 80% of their rated capacity can cause harm to the batteries.
  - Using more than one battery at a time requires the proper wiring harness so that the voltage is no more than 25.2V. Over voltage will cause serious damage to electrical equipment.
  - Using more than one battery at a time requires weight and balance checks. Proper CG is critical to performance. Airframe must not be overloaded.
  - Propellers must be balanced to avoid excessive vibration.
  - GPS/Compass must be facing forward.
  - Do not use GPS Mode without GPS lock.
  - Use low strength thread locking compound on all screws.

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- Wireless Video and Data ranges vary considerably on many factors including weather, equipment, and obstructions. Be prepared for com failures.

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SECTION 2
LIMITATIONS

- AIRSPEED LIMITATIONS
  - Vne – Velocity to Never Exceed: 15 m/s
  - Va – Typical Maneuvering Speed – 5 m/s

- POWER & POWERPLANT LIMITATIONS
  - 40 Amps max per motor
  - 40 Amps max per speed control
  - 320 Amps max total
  - Do not exceed 80-90% discharge of rated battery capacity
  - Do not charge batteries which are warmer than air temperature
  - Allow batteries to cool after use before charging
  - Leave an air gap between batteries when multiple batteries are used simultaneously

- WEIGHT LIMITS
  - Takeoff Weight Max: 24 lbs
    - Must be checked prior to takeoff if any change in equipment is made

- CENTER OF GRAVITY LIMITS
  - 3mm from the center of any of the three pairs of arms
    - Must be checked before every flight to ensure batteries were installed in the proper location.
    - Check all 4 pairs of arms before flight

- MANEUVER LIMITS
  - This aircraft is intended for non-aerobatic operations
  - G-loading maximum: 2G

- TEMPERATURE LIMITS
  - Operating Temp Range: -10°C to +40°C
  - In cold temperatures
    - Keep IMU at room temperature if possible before the flight
    - Keep Batteries above 5°C before flight
    - Do not fly with any frost or ice on the propellers
  - In warm temperatures
    - Batteries heat up when discharged
    - The higher the discharge rate the higher the temperature increase during use
    - At temperatures above 45°C, use of 2 or more batteries is required to lower the load on any one battery pack to keep it cooler.

- WEATHER LIMITS
  - Light dust and light rain require the use of a shield for the electronics in the center section.
  - Light dust and light rain are acceptable for the unshielded motor and ESC.

- RANGE LIMITS
  - FUEL

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- Fuel capacity is a primary limiting factor.
- Flying into the wind will use more battery power to travel the same ground distance. Higher air speeds will be required to penetrate the wind which used more battery power. Take this into account when flying a mission.
- Where possible, fly upwind at the start of a mission and downwind at the end to avoid depleting the battery before returning to base. Have alternative landing sites available in case of emergency landing.

- WIRELESS LINK
  - Wireless links will be stable in LOS (line of sight) in most conditions
  - Wireless links are always susceptible to shorter ranges due to
    - Atmospheric conditions
    - Other transmission devices in the area
    - Jamming
    - Antennas not aligned properly
    - Improper voltage
    - Antenna blockage from AV in certain positions
    - Multipath – reflection off buildings or ground which cause multiple signals to arrive at different times and/or phase.

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SECTION 3
EMERGENCY PROCEDURES

- MOTOR FAILURE
  - Operation is possible with one motor/ESC/propeller failure
    - The two adjacent motors/ESCs will be increased in thrust automatically by the flight controller to overcome the loss
    - In cases where the airframe is highly loaded the maximum rating of 40 amps may be exceeded by these two motors/ESCs
    - Operation should be terminated as soon as possible to reduce the possibility of damage to the remaining motors

- COMMUNICATION FAILURE
  - Video link failure
    - 5.8 Ghz being the shortest wavelength in general AV use has the least ability to penetrate. This link should be the first to be lost.
    - It is best to lose video first! It is the least likely to cause a crash when it fails.
    - 5.8 Ghz can lose link with little warning.
    - Ensure that the GCS station antennas are perpendicular to the AV. Do not point the antenna at the AV.
    - Yaw the AV to change the antenna position
    - Other links should still be good. Return back to the GCS until link is restored.
    - Transmitters produce heat when in operation. When overheated they may have thermal protection which interrupts use temporarily. Use of a heat sink or fan may be required especially with high ambient temperatures.
    - Higher gain antennas may be used, but do so with caution. High gain antennas are directional.
    - Multiple antennas using “diversity” can be used. Diversity is a device which determines the best signal, and uses that.
    - 5.8 Ghz even at high wattages theoretically has less range than lower frequencies. Changing to 1.3 Ghz is an option, though there are other issues to be considered.
  - RC link failure
    - 2.4 Ghz antennas can lose link with little warning.
    - Anything in between the two antennas can cause temporary signal loss especially a person.
    - Hold the transmitter up in the air and walk in the general direction of the AV (aerial vehicle).
    - Ensure that the antenna is vertical. Do not point the antenna at the AV.
    - The failsafes on the RC link should be set so that the AV returns to home. Should this require a heading change, the antenna may move into a more desirable position and link will be restored.
    - The onboard equipment may block the signal. Yaw the AV so that the antennas point towards the GCS.
    - A LRS (long range system) can be used as a permanent solution. This is higher in wattage and usually on 433 Mhz.
  - Data Link Failure
    - 900 Mhz do not lose link without some warning. When drop outs are noticed to increase in frequency that is the limit of the range.

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        - If using 900 Mhz, this is on cell phone frequency. If a cell tower is nearby it can swamp the signal. 900 Mhz may not be usable in that area. Change to a different freq. or remain closer to the AV

- LOW BATTERY POWER
    - Fail-safes can be set such that in the event of low battery power, either due to a failure or too long of a flight, the warning light on the AV will constantly flash amber. This is the first level of warning.
    - The second warning level is red flashing lights
    - Auto landing will occur when battery power is low. It may land in a tree or a lake, so this is not desirable.
    - Landing with 80-90% of battery depleted is best. Therefore landing with 17,000 mah used and 3,000 mah remaining of a 20,000 mah battery is desirable. Batteries should be drawn down equally when in use if they are both charged equally and both in relatively the same condition/age.
    - Do not mix partially charged batteries. Only use completely charged batteries.
    - Over discharging a battery below 19.8V can permanently damage the battery.

- GCS FAILURE
    - Takeover by the external pilot should happen ASAP using the RC link.
    - Most often happens due to a low battery.
    - Keep a spare 3 cell LiPoly battery with the appropriate plug to plug into the charge jack for emergency use. Most chargers are 19V output which is roughly equivalent to a 4-cell battery. 3-cell batteries may work.

- COMPASS CALIBRATION ERROR
    - If the compass is out of calibration the warning light will flash red. This is the same signal as low voltage. If the voltage is correct, there is a calibration error.
    - Recalibrate the compass following the instruction manual

- FIRE
    - Fires can occur due to a short circuit or battery failure.
    - Disconnect the battery ASAP unless there is danger in doing so if there is any electrical issue.
    - It is not possible to put out a battery fire.
    - Do not attempt to put out a battery fire. Use a fire extinguisher to put out fires surrounding the battery. A CO2 fire extinguisher is better than the powder or chemical type. CO2 does not leave a residue. Water can be used though it may cause other electrical component failures.

- FORCED LANDINGS
    - If alternate emergency landing zones should be chosen ahead of time.
    - Be sure that the LZ is clear of people to avoid any incidents.
    - Land in the nearest LZ which is clear of people.
    - Announce your intentions of landing as loud as necessary to alert people of the incoming AV.

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SECTION 4
SET UP SUGGESTIONS

- ELECTRONICS BURN IN
  - We recommend that you put weights onto the landing skids to keep the copter on the ground and run the copter at about 70% throttle for about 2 hours to burn in the electronics. Most electronic failures occur in the first 2 hours of operation.
- GPS/COMPASS MAST LENGTH
  - We found that the higher the mast, the better the GPS reception
- Nex5N vs. Nex7 vs. Canon 5D vs. Panasonic GH3
  - These cameras are excellent for stills, and very good for video. The best for video is the Panasonic GH4 with 4k capabilities.
  - We found that the Nex 5N takes exceptional quality stills and video, though most professionals use the Nex 7. The Canon 5D is better than the Nex7 due to its larger sensor.
  - Use the Panasonic GH4 if you primarily shoot video
- RADIO SET UP
  - Follow the instructions in the manual
  - We prefer the switch assignment as shown in the checklists above though feel free to modify to your liking
- COPTER COMMAND AND CONTROL
  - We recommend the use of a dual rate switch for main copter operation.
    - High rate – used to initialize the motors. The flight controller will not engage unless it sees full down throttle, full left rudder, full left cyclic and full back cyclic. However, these may be too high for normal flying. On high rate it is helpful to utilize fairly high exponential to make the stick feel soft around center. Adjust to your preference.
    - Low rate – used for typical flying. Set the end point adjustments such that full stick deflection offers the maximum speed required in normal flying. If conditions require higher flight speeds, switch to high rate. On low rate it is also helpful to utilize a small amount of exponential to make the stick feel soft around center. Adjust to your preference.
- ZENMUSE COMMAND AND CONTROL
  - We recommend the use of a dual rate switch for gimbal operation.
    - High rate – used to initialize the gimbal. The gimbal may not engage unless it sees full motion. However, these may be too high for shooting video smoothly. This is best for still photography so as to put the camera on target quickly. On high rate it is helpful to utilize fairly high exponential to make the stick feel soft around center. Adjust to your preference.
    - Low rate – used for videography. Set the end point adjustments such that full stick deflection offers the maximum speed required for videography. If conditions require higher gimbal speeds, switch to high rate. On low rate it is also helpful to utilize a small amount of exponential to make the stick feel soft around center. Adjust to your preference.
- TIMERS
  - Use of the countdown timer is a good backup method to ensure landing with battery power.
    - Set the timer for 20 minutes (or what you deem appropriate) and have it start when the throttle is over ¼. Then adjust the timer upwards until the amount of battery used is about 80-90% of the total available. If using 20,000 mah batteries, a total of 17,000 mah would be the target. Set the timer such that you have a minute or so to land after

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the alarm sounds so that you have adequate time to return to base. Adjust to your preference.

- BATTERIES
  - Replace the transmitter standard battery with a Lipoly battery to extend use times to 8 hours. Supplied batteries often last about 2 hours.

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NORMAL PROCEDURES

- PREFLIGHT CHECKLIST
  - Confirm all communication radios are operational
    - Radio with ATC
    - Radios with others in the group
  - Set a perimeter of 100 meters
    - Area must be clear of people to avoid collision
  - Check for overhead power lines and other obstacles to avoid
  - Check structural integrity
    - In event of prior crash, inspect all booms, props and motor mounts for excessive flex indicating structural fatigue/failure
  - Have a manual flight plan avoiding obstacles.
  - Load auto flight plan if using one
    - Be sure that the total flight time is under 10 minutes to avoid low battery
  - Clean lens
    - Remove lens cap
  - Ensure camera has SD card installed
    - Many flights have been wasted due to this!
  - Install batteries
    - Ensure that the straps are tight and the Velcro keeps the batteries from moving which will avoid a shift in the CG (Center of Gravity – or that it balances evenly)
  - Check CG (Center of Gravity)
    - Lift the copter on each of the 3 pairs of arms. The copter should balance properly. If not, do not fly. Rearrange the equipment such that the CG is
  - IMU pointing forward
    - The Inertial Measurement Unit is set so that it must face forward
  - GPS/Compass installed, limited free play, pointing forward
    - This device must be installed with a screw to hold it in place. It cannot vibrate easily. If it does not point forward, the corrections in ATTI and GPS mode will be incorrect and it will crash. The FC will provide a warning with constant flashing white lights.
  - Level copter using a bubble level with front pointing in correct direction for course lock – do not turn on
    - Keep in mind the best angle for pointing the landing gear in the direction that will keep the landing gear out of the shot when flying.
  - Turn on Pilot Tx
  - If using the rate gyro, set it at the correct position. This is usually a slider switch. Gains should have the range set from 200 – 350. Use the highest gain possible which does not cause oscillation.
  - Check Model Selection on Tx to be S800
  - Throttle on Tx Down
  - Return to Home switch Off
  - Adjust gain to correct position (if required)
  - Manual Flight Mode Switch to manual (not ATTI or GPS mode)
  - Flight Path Switch Off – Not Course or Home or POI
  - Check Tx battery voltage (above 7.5v)
    - These settings above are required to initialize the copter properly. If the switches are in the incorrect position, it will not initialize properly which may cause some of the functions like course lock or GPS mode to not operate properly.

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        - If the copter does not function properly after takeoff, land immediately and disconnect the copter power. Then put all the switches in the proper position for initialization and turn the power back on to the copter.
    - Count down timer should be set to 20 minutes. This can be adjusted to your flying style. The timer should engage at ¼ throttle and trigger an alarm at the proper time. This is a backup alarm in case the indicator lights on the copter are not visible.
    - Turn on Photography Tx
    - Check Model Selection on Tx – should read Zenmuse
    - Check Tx battery voltage (above 7.5v)
    - HDMI switch Off
    - Freestyle switch Off (FPV On)
        - These settings above are required to initialize the Zenmuse properly. If the switches are in the incorrect position, it will not initialize properly which may cause some of the functions like live video or gimbal operation to not operate properly.
        - If the camera or gimbal do not function properly, disconnect the copter power. Then put all the switches in the proper position for initialization and turn the power back on to the copter.
    - Engage power to copter
        - Plug in the 2 battery packs. Typically the battery packs use red T-style connectors in a parallel wire harness. This Y-harness has a yellow connector. It is preferable to connect the batteries to the Y-harness first, then plug in the yellow connector. This reduces (but does not eliminate) electrical arcing.
        - 6 quick chirps should be heard confirming 6S LiPoly batteries are recognized by the ESCs.
            - Hearing less than 6 chirps indicates fewer cell battery packs are being recognized which is incorrect. Check for improper or damaged batteries.
    - Do not move or vibrate the Squadcopter until 30 seconds after full GPS Lock
        - Initial 3 red blinks is normal meaning no GPS lock. No red flashes indicates full GPS lock.
        - Continue with checklist as you are waiting for full GPS lock, but do not move the copter.
        - If the GPS takes more than 5 minutes to lock, there is a problem with the area. It is not receiving the proper signals from the satellites. GPS signals are weak, so trees, people, buildings, terrain, weather, have an effect. Move the copter into a more open area where it can more easily see the satellites.
    - Check Copter Voltage from both Tx's (transmitters)
        - The transmitters receive a signal from the corresponding receivers. The voltages are regulated to about 5v. If the voltage is below 4.4v or above 6v do not fly. There may be power regulation issues. The receivers cannot work outside this voltage consistently. Also there is some issue if the voltage is outside that range which should be resolved before flying.
    - Engage Attitude Mode – Must achieve double amber flash
    - Engage GPS Mode – Must achieve double purple flash
    - Engage course cock mode – Must achieve double green flash
    - Disengage course lock mode. Must achieve double purple flash. Stay in this mode until just prior to takeoff, after takeoff at any time, or do not use.
    - Do not engage motors. Set throttle to center position. Must achieve single purple flash when in GPS mode.
        - To verify that the sticks are all centered properly:

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        - With throttle in the center position, use the trim buttons on the transmitter to check that the sticks are centered. Trim the roll (the stick located on the right side of the transmitter when moved to the right and left) to the right, counting the number of clicks until a double flash occurs. Then center the trim. Then move the trim to the left, counting the number of clicks until a double flash occurs. An equal number of clicks should be counted each side of center.
        - Do this check for the 3 stick movements other than throttle.
        - Center the trim such that when the stick is in the neutral position that there are equal numbers of clicks in each direction. This ensures that when the sticks are neutralized that the flight controller will recognize this signal and engage GPS mode.
    - Calibrate GPS/Compass before the first flight each day or if receiving continuous red blinks or continuous white blinks.
        - Flip the GPS mode switch 7 times very quickly from manual to GPS. End with the switch in the manual position. The indicator light will be blue. Rotate the copter about 1.5 turns in a horizontal position. A green flashing light indicates that this is complete. Then hold the copter vertically and rotate about 1.5 turns. A white flashing light indicates that this is complete. Repeat if necessary until this is completed.
    - After calibration, reset the copter by cycling battery with copter pointed in the correct heading for course lock.
    - Engage Camera
    - HDMI switch On
        - This will stop video from playing on the back of the camera and will send the video signal to the video transmitter via the HDMI connection.
    - Freestyle switch On (FPV Off)
        - This allows the camera to be operated freely through the transmitter
    - Verify camera operation
        - Operate the shutter
        - Set the focus to auto or manual. Manual setting is usually set to infinity to stop constant focusing of the camera.
    - Verify data link if installed
        - Roll the copter about 45 degrees on its side by lifting one side of the copter and resting one side of the landing gear on the ground
        - A corresponding roll should be seen on the gauge.
        - If the copter is rolled to the right, it will appear on the gauge that the horizon rolls to the left – not the right because the view from inside the copter is that the horizon rolls the opposite direction of the copter.
    - Verify altitude is about 0 via gauge on computer
        - If it is not about 0, the altitude settings for the waypoints will be off by this amount. This could cause the copter to fly at 10 meters or 30 meters if the waypoint is set for 20 meters and the altitude is off by 10 meters one way or another. If the copter thinks it is at 10 meters when it is on the ground, then it will only rise 10 meters above the ground to achieve what it believes it to be 20 meters above the ground.
        - The altitude can be reset using the ground control software by going to altitude offset.
    - Alternate Emergency Landing Sites Established

- NORMAL TAKEOFF
    - Confirm clear for takeoff with ATC
        - Necessary if within 5 miles of an airport

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        - ATC clearance is required days or weeks before flying.
    - Engage GPS mode – Double purple flash when the throttle is down.
    - Switch to Course Lock flight mode if required. Purple flashes are replaced with green flashes. Flying in course lock is not required, but helpful in many instances.
    - Announce loudly: "CLEAR PROP"
    - Move both of the sticks to the bottom left corners to engage the motors. Within 1 second move the throttle up 1/8 – 1/4. The copter should not lift off until about ½ stick is reached.
    - Verify data and video links before lifting off. If anything is not working properly, move the throttle stick to low to disengage the motors and determine a solution.
    - If all flight checks are passed, announce loudly: "TAKING OFF"
    - Advance throttle to about 3/4. Copter must jump off of the ground to avoid one skid coming up before the other skid, and the skid on the ground getting caught and flipping the copter over sideways.
    - Ascend to 3 meters. Then decrease throttle to ½ to engage the GPS hold.
    - Verify links, GPS, Attitude, etc. Should be single purple flash.
    - Verify that the copter is holding position within .5m in all directions.
    - Verify camera operation
    - Verify course lock is operational by rotating 90 degrees and pushing forward on stick.
    - Verify copter stability. If unstable, land and reset gains, recalibrate, or retest as necessary.
    - Proceed with manual mission or
    - For autopilot operation
        - Ascend to 10 meters
        - Command AVO to proceed with mission.
            - Pilot should say "It's yours"
            - Response from AVO "I have it"
    - Manual pilot/observer must monitor the informational LED and be ready to take over in manual mode when necessary.
        - White flashes indicates flight controller issue
        - Amber flashes indicates low battery
        - Red flashes indicate loss of GPS or severe battery condition
            - Quick decisions are required when red flashes are indicated
            - 10 seconds or more of loss of GPS signal will stop waypoint guidance and any GPS hold and put into manual mode.
            - Red indicator light battery warning requires immediate landing
    - Manual pilot to request copter flight battery voltage readout from AVO periodically.
        - Reset the first and second indicator lights as required for your set up.
        - When recharging the batteries, the goal is to put 4,000 mah into a 5,000 mah battery pack. Adjust the voltage warnings to your style of flying.
        - Also use the countdown timer on the transmitter. This gives a good indication of battery level because the current used is fairly constant from flight to flight.

- POST LANDING
    - Note flight time from transmitter. Write this down in the log book.
    - Note battery power used during the flight. Write this down in the log book.
    - ALWAYS disconnect the main power to the AV first, then turn off the transmitter.

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- Check motor temperatures by touching them with your fingers. Any motors which are excessively hot should be further inspected and possibly replaced.
- Check battery temperatures by touching them with your fingers. Battery temperatures should not be hot to the touch. Battery temperatures should be slightly above ambient.
- Inspect all components especially the propellers for wear.
- Note in logbook which batteries were used to calculate life cycle.

- AIRCRAFT FLIGHT LOG BOOK (Can be purchased inexpensively)
  - Keep a log of all flights.
    - Date
    - Time of Day
    - Time in Operation (in hours)
    - Battery serial numbers
    - Mah used in flight
    - Location
    - Pilot, Observer, Sensor Operator Names
    - Flight Objective
    - Remarks

- AIRCRAFT MAINTENANCE LOG BOOK (Can be purchased inexpensively)
  - Keep a log of significant inspections, tests, repairs, alterations, equipment changes.
    - Date maintenance is performed
    - Accumulated hours of operation
    - Remarks

- PILOT LOG BOOK (Can be purchased inexpensively)
  - Keep a log of all flights. Include the following:
    - Aircraft flown
    - Aircraft serial number
    - Date
    - Time of Day
    - Time in Operation (in hours)
    - Location
    - Flight Objective
    - Remarks

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SECTION 5
PERFORMANCE

- FLIGHT TIMES
  - The AV is designed to hover at high efficiency. Hovering is much less efficient than flying on a wing, thus flight times are low compared to fixed wing aircraft.
  - All the weight of the AV is supported by power from the batteries. As the batteries are used in a flight, the amount of power available decreases. Therefore the power reserve is constantly decreasing as the battery is being used. Thus loading a rotorcraft above its limit is not recommended. While the AV may have enough power to lift off initially on a full charge, the power reserve at partial charge may be too low to allow for maneuvering and will result in a crash.
  - High lateral speeds will add lift to slightly improve efficiency. The rotors act similar to fixed wings at higher speeds. This increase in efficiency may be negated by the increased power consumption of forward flight.
  - High winds or gusts decrease efficiency/flight time. The motors work harder to hold position.
  - As weight increases flight times decrease.

- WIRELESS TRANSMISSION
  - Refer to the specific manuals for performance ratings.
  - Wireless communications utilized provide acceptable communication for LOS.
  - In general:
    - LOS is required
    - The higher the GCS antennas, the better the range
    - Any freq. at may have severe degradation due to location to other admitters such as cell towers
    - RSSI (Received Signal Strength Indication) should be monitored for indication of communication drop out.

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SECTION 6
WEIGHT AND BALANCE EQUIPMENT LIST

- CG
  - CG is critical to the efficient operation of any AV
  - When components are shifted, the CG will be altered.
  - The main components which are moved on a regular basis are the sensors and the batteries.
  - The sensors are typically in the front of the AV, and the batteries are located in the correct position to offset all the components on the AV.
  - The CG must be tested after any change to the components or their placement.
  - The CG should be tested by lifting the UV with fingers on the bottom of the arms. Check all 3 pairs of arms. The CG should be no more than 2mm off in any on the 3 checks. The closer the CG is to the centerlines of the arms the more efficient and the more stable the AV will be.
- WEIGHT
  - Weight is critical to the operation of any aircraft
  - Weight is especially critical to a rotor wing aircraft. At full throttle the motors have a finite amount of thrust. All the weight is lifted by the battery power, there is no wing to assist in providing lift.
  - As the batteries are operated, they lose power. At full charge they have about 25v. At 20% remaining capacity they have about 21v. This is a loss of 8% of the power available which is significant.
  - Do not overload the aircraft or there will not be sufficient reserve power to maneuver at low battery levels.

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SECTION 7
AIR VEHICLE AND SYSTEMS DESCRIPTION

- FUEL/BATTERY REQUIRED
  - Manufacturers: Various COTS suppliers.
  - Refer to manufacturer data sheet.
  - Battery chemistry required: Lithium Polymer
  - Battery Capacity: 16,000 mah (minimum)
  - Battery cell count required: 6S (6 cells in series)
  - Battery Voltage: 21V minimum at hover, 22.2V nominal, 25.2V maximum
  - Battery Minimum Rated Discharge Rate: 20C minimum
  - Batteries used simultaneously: 1-4 typical
  - Recommended Battery Discharge Amount: 80-90%

- WERELESS COMMUNICATIONS
  - Refer to the specific manuals for performance ratings.
  - Never power a video transmitter or receiver without an antenna connected or overload failure will occur.
  - Wireless communications utilized provide acceptable communication for LOS.
  - In general:
  - LOS is required.
  - Lower frequencies penetrate objects such as trees better than higher freqs.
  - Lower freqs have longer range than high freqs
  - Higher freqs can transfer more data than lower freqs
  - Higher freqs use smaller/shorter antennas
  - The higher the GCS antennas, the better the range and reception
  - Any freq at may have severe degradation due to location to other admitters such as cell towers
  - Range must be constantly monitored.
  - Alternate antenna types may be utilized to improve link/range. Patch, helical, omni, etc. can be substituted. They must be verified before use.
  - Alternate freqs may be utilized to improve link/range.

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SECTION 8
HANDLING, SERVICE AND MAINTENANCE

- PROPELLER CARE
  - Propellers must be checked each flight for nicks or cracks
  - Propellers are designed to last indefinitely if they do not impact dust, dirt or more.

- BATTERY CARE AND USE
  - Refer to instruction sheet included from the battery manufacturer. Typical information follows.
  - Batteries are highly flammable and can explode, especially when fully charged. Improper charging, vibration, impact, high discharge, etc. can lead to explosion and fire. Batteries must be charged under constant supervision and using proper precautions.
  - Batteries fully charged must be handled with extreme care.
  - Any battery which puffs up is considered damaged and must not be used. It is in a dangerous state. Never charge a puffed up battery.
  - Any battery which holds less than 80% of its rated capacity should be discarded.
  - Cycle test each battery after every 50 cycles or if a battery is suspected to have lost as significant amount of its capacity to determine the current capacity.
  - Properly dispose of batteries. First discharge the battery fully using a battery cycler. Bring to a recycler such as a home improvement store.
  - Always charge flight batteries under “balance” mode.
  - Flight Battery Recommended Charge Rate: 1C which takes approximately 1 hour to charge
  - Flight Battery Maximum Charge Rate: May exceed 5C. Charge rates higher than 1C will decrease life cycles. Maximum charge rating per the manufacturer will provide 300+ cycles. Use the lowest charge rate which is practical.
  - Battery Rest Time between discharging and charging: 30 minutes minimum, 1 hour maximum.
  - Do not charge if the battery is more than 2°C warmer than ambient, especially if the temperature is above 20°C. The outer surface is cooler than the inner core after use. Damage will occur when charging a warm battery.
  - Recommended Battery Discharge Amount: 80%. Using more of the capacity of the battery will decrease the life cycles
  - As battery temperature approaches freezing the capacity of Lithium Polymer batteries decrease. Keep warmer than 5°C before installing into the UV (unmanned vehicle).
  - Battery capacity decreases at higher discharge rates. Using more batteries decreases the discharge rate of each battery thereby extending individual battery capacity slightly.
  - Lower discharge rates improve the life cycles.
  - Batteries are rated at greater than 300 life cycles. 1,000+ life cycles are possible.
  - Batteries must not be stored above 60% charged state for extended periods.
  - Batteries should be stored below 25°C for extended periods
  - Store batteries between 40% - 60% charged state. Fully charge just before use.
  - Fully charged batteries which are not to be used within 24 hours should be discharged to 40% - 60% charged state using the battery discharger.
  - Using more than one battery at a time requires the proper wiring harness so that the voltage is no more than 25.2V. Over voltage will cause serious damage to electrical equipment.

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- PREVENTATIVE MAINTENANCE
    - ANNUAL INSPECTION (SUGGESTED)
        - If the airframe has in excess of 300 hours in a one year period, an annual inspection must be completed by an approved technician.
        - An approved technician should disassemble the AV and inspect all components for wear and replace any components as required.
        - Test all batteries for capacity.
        - Upgrade firmware and software to latest revisions

    - 500 HOUR PM (SUGGESTED)
        - An approved technician should disassemble the AV and inspect all components for wear and replace any components as required.
        - Replace all 8 motors.
        - Test all batteries for capacity.
        - Upgrade firmware and software to latest revisions.

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SECTION 9
SUPPLEMENTS

COTS components have been utilized in the construction of this AV. All instruction manuals, operating handbooks, warning notices, and more are available as separate documents. Components which may have separate documentation follow. Links to these documents are available on the website. Print out the significant documents and keep in a notebook with the copter at all times.

AIRFRAME
AUTOPILOT SYSTEM
BATTERIES
BATTERY CHARGER
CAMERA MANUAL
CAMERA GCS
DATA WIRELESS LINK
GIMBAL CAMERA MOUNT
GIMBAL CAMERA MOUNT SERVOS
LAPTOP COMPUTER
MOTORS
ONBOARD REGULATOR
PROPELLERS
RC/MANUAL COMMAND & CONTROL SYSTEM
SPEED CONTROLS (ESCs)
VIDEO CAPTURE HARDWARE
VIDEO CAPTURE SOFTWARE
VIDEO WIRELESS LINK

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